Technical Reviewers' Rating Summary

Proposal Number G-39-01 Application Title ThermFlo, a novel tecl Submitted By Drake Water Technolo Request For $329,000.00 Total Project Costs $671,095.00

Section A. Scoring

Statement	Weighting Factor	G-39-01A	G-39-01B	G-39-01C	Average Weighted Score
1. Objectives	9	**3**	**3**	**4**	**27**
2. Achievability	7	**3**	**4**	**4**	**21**
3. Methodology	8	**3**	**3**	**2**	**16**
4. Contribution	8	**4**	**4**	**3**	**24**
5. Awareness / Background	5	**1**	**4**	**3**	**10**
6. Project Management	3	**3**	**3**	**4**	**9**
7. Equipment / Facilities	2	**2**	**5**	**4**	**6**
8. Value / Industry - Budget	4	**3**	**4**	**4**	**12**
9. Financial Match - Budget	4	**3**	**3**	**3**	**12**
Average Weighted Score		**146**	**178**	**167**	**163**
	Total: 50				**250 possible points**

OVERALL RECOMMENDATION			
FUND		**X**	
FUNDING TO BE CONSIDERED	**X**		**X**
DO NOT FUND			

Section B. Ratings and Comments

1. The objectives or goals of the proposed project with respect to clarity and consistency with North Dakota Industrial Commission/Oil and Gas Research Council goals are:

   The proposal clearly states in the Standards of Success section (pg 10) that this technology would promote environmentally sound development of oil and gas by reducing the environmental footprint of the extraction, processing and transportation activities.
   - Reviewer: G-39-01A
   - Rating: 3

   The objective is stated throughout the application. It is to construct a mobile ThermFlo unit for deployment to a site in ND for the demonstration of on-site clean-up of contaminated soils and solids, i.e. Special Waste. ThermFlo is a product of Drake Water Technologies (DWT) and is a "cradle to grave" thermal process for complete remediation of soils, drill cutting contaminated with organics. It utilizes catalytic combustion.
   - Reviewer: G-39-01B
   - Rating: 3

   Objectives are consistent and clear
   - Reviewer: G-39-01C
   - Rating: 4

2. With the approach suggested and time and budget available, the objectives are:

   The construction of the ThermFlo treatment unit is likely to be constructed on time and within budget. My concern is with the treatment rate. The ThermFlo technology estimates a max treatment of 4 to 6 tons of impacted material per hour. Other conventional thermal desorption technologies can treat 35 to 55 tons of material per hour depending on the moisture. Even at the higher processing rate this technology has proven not to be cost effective.
   - Reviewer: G-39-01A
   - Rating: 3

   The application contains a timetable of 4.5 months for fabrication, deployment, and demonstration of the ThermFlo unit. The designated fabricators, P&S Fabricators, Inc., have experience working on other projects for DWT. The budget and timetable appear to be in line. The timetable is dependent on permits and site selection. The application states they plan to demonstrate "at an approved drilling site in North Dakota" (page 7). No specific site was referenced.
   - Reviewer: G-39-01B
   - Rating: 4

   No comment
   - Reviewer: G-39-01C
   - Rating: 4

   Ron Drake (DWT) -- ThermFlo throughput is strongly dependent on composition (fuel value and moisture) of the feed material. The throughput of the ThermFlo unit described in the grant application was based on the needs of DWT's industrial partner, NOV. Estimated throughput values shown in the grant application were for invert drill cuttings exhibiting high fuel value (7,000 BTU/lbm) and relatively low (5 wt%) moisture. These materials are processed relatively slowly because excess air is used to maintain reasonable (850 C) oxidation temperature. Contaminated soils exhibiting low heating value (1,200 BTU/lbm) and moisture (5 wt%) can be processed at throughput exceeding 15 T/hr with that same ThermFlo unit. ThermFlo processing rates are quite high for a robust, single load, highly mobile system. Because ThermFlo does not require supplementary fuel, afterburners, or sophisticated off-gas treatment systems, and produces solids that are immediately suitable for on-site surface use or spreading, specific process and disposal costs are much lower than those exhibited by competing thermal systems, none of which are based on low-temperature, catalytic, thermal oxidation.
   - Applicant

3. The quality of the methodology displayed in the proposal is:

Thermal desorption technology has a long proven history of successfully treating petroleum based hydrocarbons. However, the proposed ThermFlo technology is the first to address the brine and fugitive emission constituents. Based on result from the controlled pilot test there is some evidences to suggest this technology can be performed at the field level. It is important to note that the analytical data presented is not compelling and difficult to discern the true effectiveness of the proposed technology. I would like the proposal to describe the following in more detail: • More analytical data be presented from the controlled pilot tests. Specifically, I would prefer to see more analytical data for the brine constituents. It was poorly described how the pretreated material can have a chloride concentration of 215 ppm but the final treatment presents 2,330 ppm chloride. • Explanation for why there is such a sharp decrease in pH. These low values may pose environmental consequences. • How are the fugitive emissions captured? • At what thermal temperature does the process take place? • The material processed in the pilot was drill cuttings. How will this technology work on soil? Have they treated soil, and if so, what was the clay content of the soil? • What was the moisture content of the processed material?
- Reviewer: G-39-01A
- Rating: 3

The application states that
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ThermFlo was derived from technology developed for weapon demilitarization for the US-DOE in the 1980s and developed for clean up of hazardous wastes. It is proven technology as referenced in two previous sites (page 6). It states the project will be tested on a drill site but does not give specifics to the site or how the unit will be integrated in the drilling process.
- Reviewer: G-39-01B
- Rating: 3

Methodology was scant. Methodology section read more like a sales brochure than a scientific methodology. Little detail was provided to indicate how the integrated auxiliary systems will be developed and incorporated. Little information on the maturity of these systems was presented. Will these systems be truly developed with this grant money, or will they merely be applied? The methodology section indicates that ThermFlo is well-demonstrated, leaving the reviewer to conclude that the real research here is in applying the auxiliary systems, but the remainder of the proposal does not tightly focus on this.
- Reviewer: G-39-01C
- Rating: 2

Ron Drake (DWT) – Reviewers repeatedly refer to ThermFlo as thermal desorption technology. That is not correct. ThermFlo is a low-temperature catalytic oxidation technology. NDIC limitations on grant application length and content prevented DWT from fully describing the novel technical aspects of the proposed ThermFlo unit. Previously developed circulating fluidized bed technology has been used successfully (>99.9999% destruction removal efficiency) to treat soils contaminated with military, hazardous, and hydrocarbon wastes. Nevertheless, the previously developed technology has suffered from several major drawbacks that DWT has now eliminated by innovative developments: 1. Tall (>22-ft) vertical reaction chamber – Previous circulating fluidized bed reactors were difficult to transport and erect on site, and required multiple loads for deployment. Furthermore, mechanical stresses on refractory linings (reaction chamber, hot cyclone, loop-seal) from repeated transport and erection activities limited unit mobility and useful life between overhauls. The reaction chamber for the ThermFlo unit proposed in the grant application exhibits a greatly reduced vertical profile (~8-ft tall) despite exhibiting increased (3 to 5 sec.) gas residence time at temperature. The reduced vertical height and simplified oxidation chamber design require no field erection, and greatly reduce refractory stresses, thus increasing system reliability, mobility, and duty cycles between overhauls, which greatly reduces annualized operating costs. 2. Limited feed flexibility – Previous circulating fluidized bed reactors were optimized for treating contaminated soils using refined supplementary fuels (natural gas, fuel oil), and could not be reliably operated in an "auto-thermal" mode when processing fuel rich feeds. Furthermore, these units could not recuperate off-gas waste heat in order to reduce fuel requirements. The DWT ThermFlo unit has been designed to overcome these limitations by using a novel high-temperature off-gas recuperator that can recuperate substantial energy when processing fuel-lean feed materials and that can dump excess energy when processing fuel-rich materials. Furthermore, the DWT ThermFlo unit exhibits a much improved I&C system that can operate, in a fully automated mode, using waste fuels such as tank bottoms, rag layer, slop oil, biomass, etc as the sole source of process energy. These features also greatly reduce specific operating costs. 3. Production of high-pH solid residuals – Thermal processing (850 C) of soils or solids containing alkaline earth and alkali metal carbonates and bicarbonates results in partial conversion of these species into their respective oxides. Upon wetting or leaching, the oxides first convert into their respective hydroxides, thus generating leachate exhibiting high pH. Upon prolonged (days to weeks) exposure to atmospheric carbon dioxide, the hydroxides will react to again form the parent carbonates or bicarbonates. The DWT ThermFlo unit greatly accelerates the solids neutralization process by contacting discharged solids with saturated, cooled, and carbon dioxide enriched off-gas. This renders treated solids exhibiting leachate pH<8.5, and suitable for immediate surface use or spreading. 4. Production of high-chloride solid residuals – Unlike most soils, drilling residues often contain substantial fractions of chloride salts. Traditional thermal treatment of these residues results in product solids that contain substantial quantities of leachable chloride, rendering said residues unsuitable for surface use or disposition. The DWT ThermFlo unit has demonstrated excellent partitioning of chlorides to the off-gas stream where they are captured and concentrated into a low-pH, dense, salt brine or low-volume salt cake for ultimate disposition by sale, injection, or land-filling. The presumptive mechanism for chloride partitioning is reaction of salts with mineral species and water to form silicates and HCl gas. (e.g. 2 NaCl + SiO_2 + H_2O □ Na_2SiO_3 + 2 HCl, K_{850} = 1.33). The HCl is scrubbed from the off-gas in the first (high-energy) stage of a 2-stage wet scrubbing system that produces a reduced-pH chloride brine plus warm (~70 C), particulate-free, saturated gas. The saturated gas is cooled in a low-energy direct contact condenser to produce clean water plus a cooled (~30 C), saturated, CO_2-enriched off-gas for feed to the solids neutralization and discharge auger.
- Applicant

4. The scientific and/or technical contribution of the proposed work to specifically address North Dakota Industrial Commission/Oil and Gas Research Council goals will likely be:

The thermal desorption technology is proven. The scientific contribution of this technology will be if it can address the brine constituents of concern.
- Reviewer: G-39-01A
- Rating: 4

If successful, this has the potential to impact disposing of drill cuttings and provide an on-site remediation for oil field spills. It is an on-site "cradle to grave" process. Truck transportation for these sites should decrease. Also, less drill cutting and contaminated soil would be disposed of at permitted disposal sites. This project aligns with the NDIC goal to "Encourage, and promote the use of new technologies and ideas that will have a positive, economic and environmental impact on oil and gas production". Also, it should "help reduce the footprint of oil and gas activities".
- Reviewer: G-39-01B
- Rating: 4

Considering that ThermFlo has already been well-demonstrated, the system is likely to achieve the desired processing of contaminated solids. The real advancement may be in the integration of auxiliary systems to ensure compatibility with evolving air emissions standards.
- Reviewer: G-39-01C
- Rating: 3

Ron Drake (DWT) – The ThermFlo system proposed in the NDIC grant application was specifically designed to fulfill the primary functional and

operational requirements (material composition, throughput, footprint, mobility, product quality, regulatory compliance, cost-of-treatment, etc.) set by NOV for on-site, real-time processing of invert drill cuttings produced by the highest-capacity, single-pad, multi-well, drilling rigs currently operating in the Williston basin. The proposed ThermFlo system has been developed and engineered to provide a complete solution to a costly and significant issue that adversely impacts the environment and oil and gas production in North Dakota. On-site, low-temperature catalytic oxidation of hydrocarbon contaminated drilling residues with salt partitioning promises to greatly reduce cuttings disposal costs and liabilities associated with handling, stabilizing, transportation, and land-filling, as currently practiced. Furthermore, low-temperature catalytic oxidation produces virtually no thermal NOX or CO, and neutralization of high-pH solids with CO2-enriched off-gas minimizes the carbon emissions "footprint" of the ThermFlo process. As designed, the ThermFlo system will comply with all current ND-DOH emissions criteria.
- Applicant

5. The background of the principal investigator and the awareness of current research activity and published literature as evidenced by literature referenced and its interpretation and by the reference to unpublished research related to the proposal is:

   This proposal did not contain a literature review and briefly reference that this technology originated from work conducted by the US-DOE during the 1980s.
   - Reviewer: G-39-01A
   - Rating: 1

   DWT deployed a similar unit to the ThermFlo to operations in Canada in 2014. The unit, CuttFlo (page 11), is designed to recover valuable organic products from hydrocarbons. DWT employees also have experience working on government projects utilizing the same technologies in the 1980s and 1990s (page 6).
   - Reviewer: G-39-01B
   - Rating: 4

   Undoubtedly, DWT knows of competing technologies currently being demonstrated in North Dakota and elsewhere. The reviewer is familiar with at least two competing offerings highly analogous to DWT's ThermFlo. No mention is made of these competing technologies in the proposal. A natural question: Does ND benefit from application of public R&D funding to advance a technology analogous to others currently available in an active marketplace?
   - Reviewer: G-39-01C
   - Rating: 3

   Ron Drake (DWT) -- Length limitations for the original grant application precluded detailed literature review and analysis. However, DWT and NOV did perform substantial "needs" and market analyses before embarking on a 2-year collaborative ThermFlo development program for cuttings treatment. Major finding were: A. Currently used thermal desorption technologies (kilns, screws, hammer mills, microwave ovens, IR ovens, roasting ovens, etc.) are not cost-effective in a "down" oil market due to reduced value of organic product, low throughput due to poor energy utilization (indirect heat transfer), presence of substantial moisture in invert fluids and drilling residues, and in some cases mechanical complexity, and high maintenance requirements. B. High- and moderate-temperature incineration technologies (slagging cyclone combustors, direct fired kilns, rotary kilns, induction furnaces, electro-melt furnaces, joule heated melters, etc.) generally require high-cost refined fuels or electricity for process energy, and require sophisticated and high-maintenance off-gas treatment systems and/or afterburners to remove particulate, VOCs and thermal NOX. High temperature incinerators are generally not suited for mobile operation and are subject to fouling from slag and agglomerate formation when treating mineral solids contaminated with salt. C. No currently available technologies meet the unique functional and operational requirements for real-time, on-site, thermal oxidation treatment of invert fluids and drilling residues, to render solids suitable for immediate use or land spreading, in compliance with ND environmental regulations.
   - Applicant

6. The project management plan, including a well-defined milestone chart, schedule, financial plan, and plan for communications among the investigators and subcontractors, if any, is:

   No comment
   - Reviewer: G-39-01A
   - Rating: 3

   The management plan provides deployment of the unit, as well as training and oversight. They will evaluate hydrogen contaminated materials both pre- and post-treatment for analysis of destruction removal efficiencies, chloride partitioning, and TENORM concentrations. There is a financial plan and timeline included.
   - Reviewer: G-39-01B
   - Rating: 3

   Schedule and budget appear to be well-planned. The teaming described seems to facilitate active communications among partners with equal vested interests in project success.
   - Reviewer: G-39-01C
   - Rating: 4

7. The proposed purchase of equipment and the facilities available is:

   It is unclear why the North Dakota Industrial Commission (NDIC) should purchase the equipment when Drake Water Technologies, Inc., (DWT) retains the patent rights. Furthermore, the proposal poorly justified why DWT is requesting money for project administration and engineering when they will be providing these services and will profit if the demonstration is successful. I feel these are costs they should be willing to offer to the demonstration. Also, if the NDIC pays for the equipment then they should retain any patent rights for this technology.
   - Reviewer: G-39-01A
   - Rating: 2

   The line item of "Equipment" (total $445,000 page 14) on the budget is not detailed. The assumption is this is for the ThermFlo unit. The ThermFlo unit utilizes thermal catalytic combustion and is essential to the project.
   - Reviewer: G-39-01B
   - Rating: 5

   No comment
   - Reviewer: G-39-01C
   - Rating: 4

   Ron Drake (DWT) --The subject ThermFlo system is the culmination of over 2 years of collaborative development work by DWT and NOV, and embodies significant evolution, innovation, and improvement over previously developed circulating fluidized bed oxidation systems, and is targeted to

provide a comprehensive on-site solution for invert cuttings remediation and disposal. Estimated sunk costs incurred by DWT and NOV over the past 2 years for ThermFlo pilot plant construction and testing, laboratory analyses, engineering, design, and process modeling, exceed $1-million. In addition, DWT has incurred sunk costs of over $900,000 during the past 6 years to support fluidized bed operations research, off-gas cleanup technology development, and fluidized bed control system development. That work is directly applicable to the proposed grant work, and is NOT included in the grant application financial roll-up. The proposed ThermFlo unit is truly a first-of-its-kind process system, developed and designed to fulfill a unique oil field mission. Although the core technology (fluidized bed catalytic oxidation) is well proven and demonstrated on a commercial scale, DWT has conceived, developed, tested, and integrated several innovations (e.g., low profile reactor, compact high temperature recuperator, chloride partitioning, solids neutralization, omnivorous fueling, feed flexibility, simple I&C) that will allow the proposed ThermFlo system to fulfill its unique mission of providing economical, single load, on-site treatment and disposition of invert drilling residues.
- Applicant

8. The proposed budget “value”1 relative to the outlined work and the commitment from other sources is of:

   It is difficult to determine the true "Value" of the work and other source commitments. Most of this cost is captured in labor. If this demonstration were preformed in a true research setting the labor costs would be much less and the technical skill would be greater.
   - Reviewer: G-39-01A
   - Rating: 3

   The science of the project could be tested in a research setting. To understand the practicality and how it will be integrated with field or drilling operations it should be tested on-site.
   - Reviewer: G-39-01B
   - Rating: 4

   DWT is requesting relatively minor financial support from OGRP. If the project delivers on stated objectives, it seems the project value may be justified.
   - Reviewer: G-39-01C
   - Rating: 4

9. The “financial commitment”2 from other sources in terms of “match funding” have been identified:

   National Oilwell Varco (NOV) is committing 43% of the demonstration costs with other stake holders contributing an additional 7.5%. These contributions make up 50.5% of the demonstration costs.
   - Reviewer: G-39-01A
   - Rating: 3

   The budget includes 51% from industry. This reaches the threshold defined by the NDIC. Participation includes vendors but does not include primary beneficiaries of the project such as field or drilling operations.
   - Reviewer: G-39-01B
   - Rating: 3

   The financial commitment from other sources is essentially at the minimum required by OGRP.
   - Reviewer: G-39-01C
   - Rating: 3

1 “value” – The value of the projected work and technical outcome for the budgeted amount of the project, based on your estimate of what the work might cost in research settings with which you are familiar. A commitment of support from industry partners equates to a higher value.

2 “financial commitment” from other sources – A minimum of 50% of the total project must come from other sources to meet the program guidelines. Support less than 50% from Industrial Commission sources should be evaluated as favorable to the application; industry partnerships equates to increased favorability.

General Comments

It is my opinion that the thermal desorption component of the proposed ThermFlo technology has little merit as this technology already exists. However, if this technology can address the brine constituents while capturing fugitive emissions created during the treatment process then this technology has merit as a novel technology. Note, the analytical data presented to justify this proposal is lacking. I suggest requesting more information before coming to any conclusions on this proposal. If this is not possible I recommend not funding this proposal as presented due to the non-persuasive brine analytical data.
- Reviewer: G-39-01A

The successful test of the ThemFlo could impact the future of drilling operations and spill remediations. The on-site "cradle to grave" would result in reduced truck traffic and decrease the volume of waste to ND permitted disposal facilities. Some questions or concerns are: 1) Is it approved to operate in a hazardous area, i.e.. a Class I Division II? 2) What pressures and temperatures does the unit run? It states (page 22) the catalytic combustion of 850 C. 3) The volume of the ThermFlo unit is 4 to 6 tons/hr. How does this relate to the volume of wastes generated at a drill site? Also, how would it relate to remediation of a spill site area, i.e. a 100' x 100' x 2' impacted area? How long would it take to remediate the site? 4) A goal or intent of soil remediation is to return the land to its original use. In other words, if the land was productive farmland than the remediation is intended to return it back to productive farmland. This proposal refers to ThermFlo process as "producing clean solids that can be left on site" (page 4). Are the "clean solids" returned to productive farmland? 5) The application states utilizing quench water in brine mud makeup. Has this been proposed to any drilling operators (mud engineers)? If so, what is their response? 6) Industry support for the project is from vendors. Were field or drilling operators approached? 7) What is the estimated cost to the consumer? 8) Are there results to report on from the CuttFlo unit operating in Canada?
- Reviewer: G-39-01B

Overall, the proposal presents as a purchase of another copy of proven equipment. Had the proposal focused on the auxiliary equipment required to expand the number of applications suitable for this equipment, the review scores may have been higher. As written, it seems that DWT is asking for OGRP funds to buy down the cost of its next installed unit, and to help DWT expand its market footprint. This may still be within the interests of OGRP (not for the reviewer to judge), but it is not proposed as advancing R&D.
- Reviewer: G-39-01C